Initial Considerations for the EMCal of the EIC detector

A.Bazilevsky, BNL

EIC-YR-Detector-Calorimetry Group

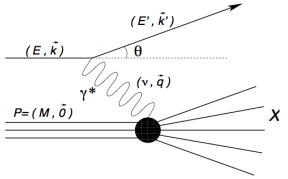
Temple University, March 19-21, 2020

EMCal at EIC

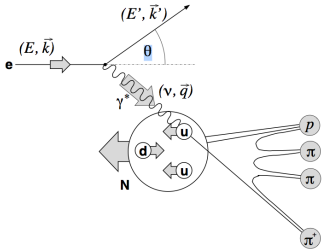
Electron/photon PID, energy, position:

Coverage (in rapidity and energy), resolutions, granularity, projectivity

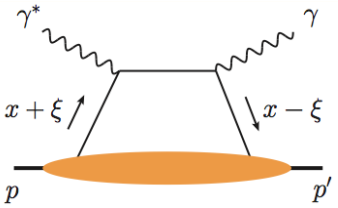
Inclusive DIS: scattered electron



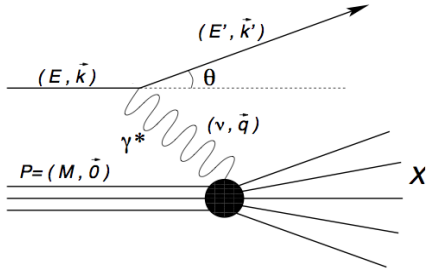
Semi-Inclusive DIS: $\pi 0$



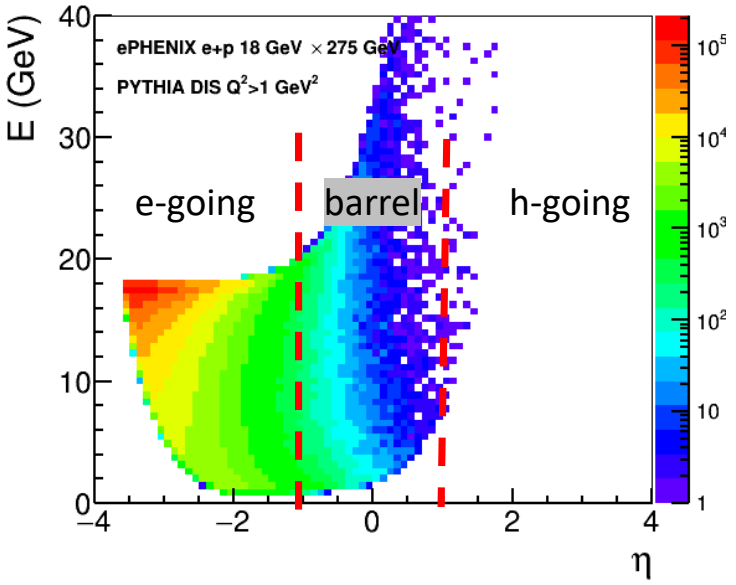
Exclusive DIS: DVCS photons, J/ψ→ee etc.



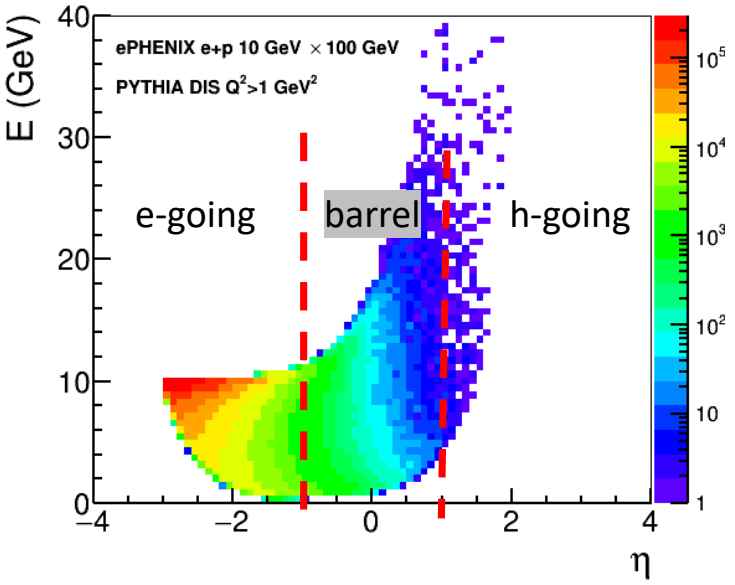
Inclusive DIS: scattered electron



e+p 18x275 GeV

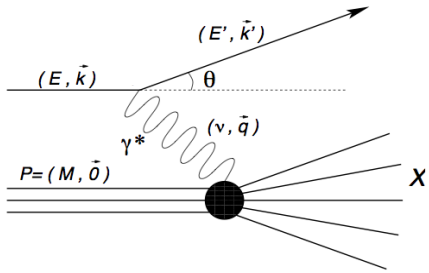


e+p 10x100 GeV

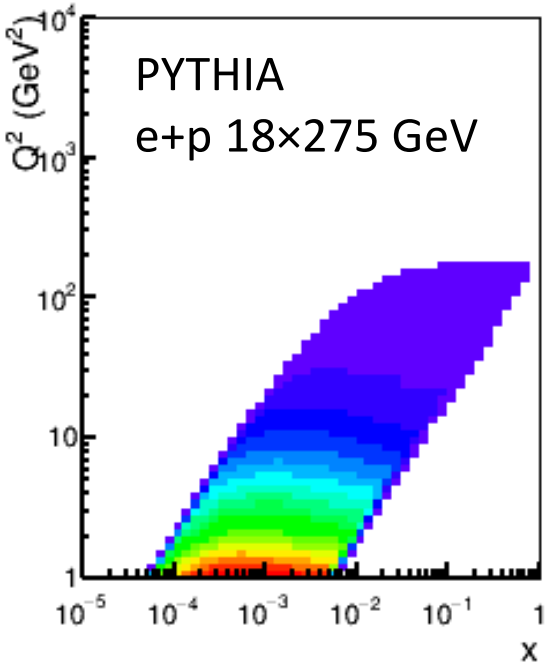


Mostly scattered in backward (e-going) and barrel
Electron energy varies from 0 to e-beam energy in backward (e-going)
And to higher energy in barrel and h-going region

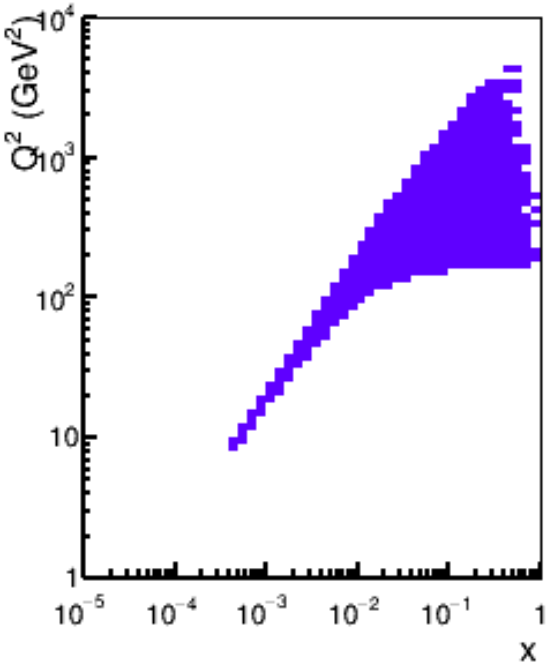
Inclusive DIS: Q^2 vs x



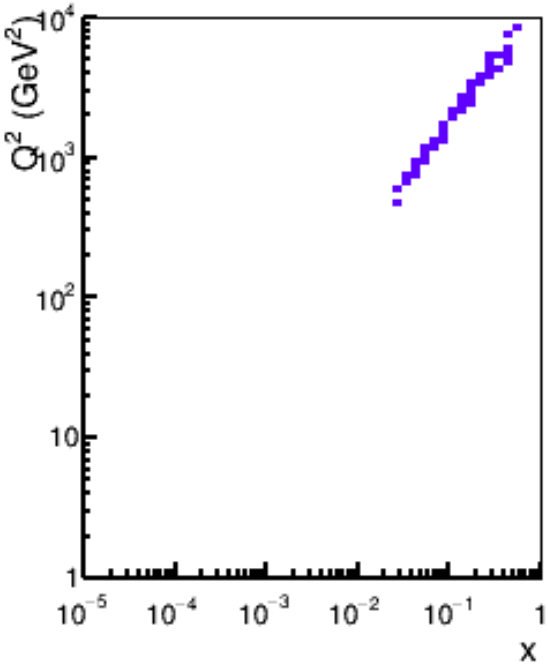
η<-1 (e-going)



-1<η<1 (barrel)

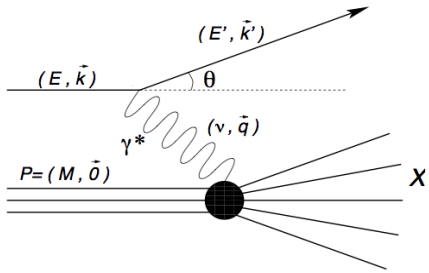


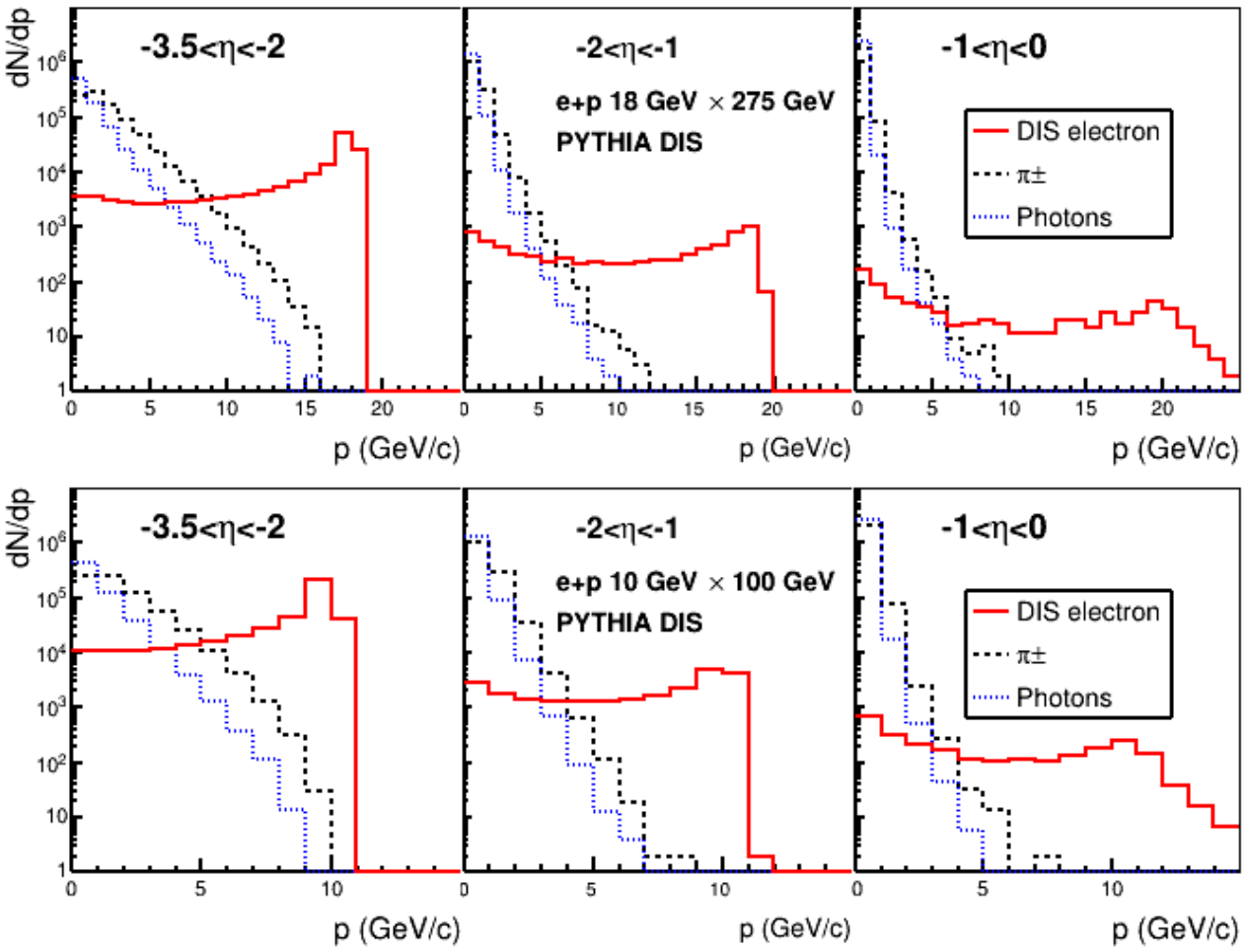
η<1 (h-going)



Low x and Q^2 probed in backward (e-going) direction
High Q^2 probed in barrel and forward (h-going) direction

Inclusive DIS: background



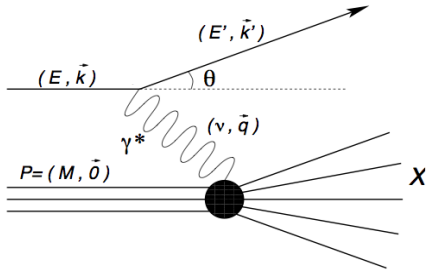


18x275 GeV

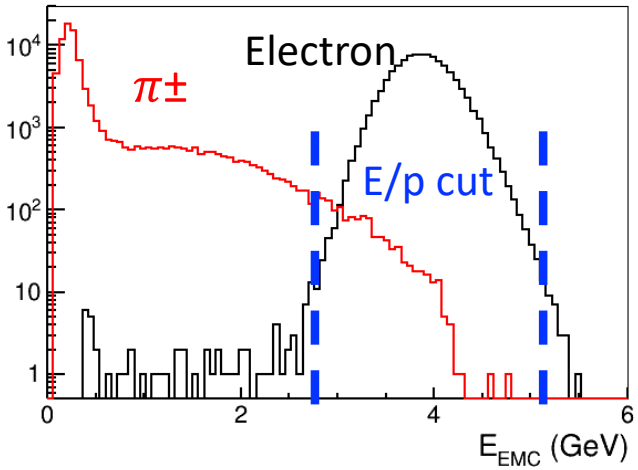
10x100 GeV

Clean measurements at higher momenta
Huge background at lower momenta

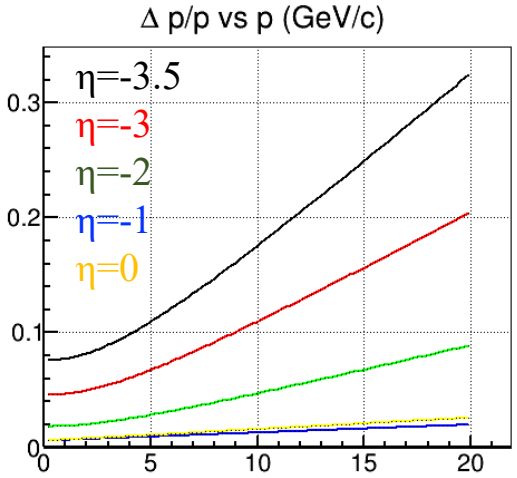
Inclusive DIS: Hadronic Background Suppression



EMCal response to p=4 GeV/c
(GEANT4 for SPACAL-like EMCal)



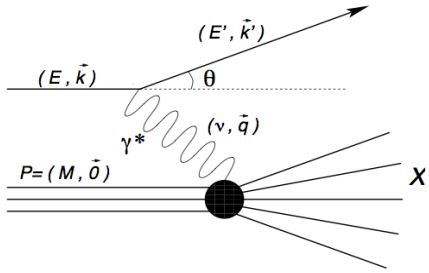
σ_p/p for BaBar-based setup
(Fun4All-GEANT4 simulation)



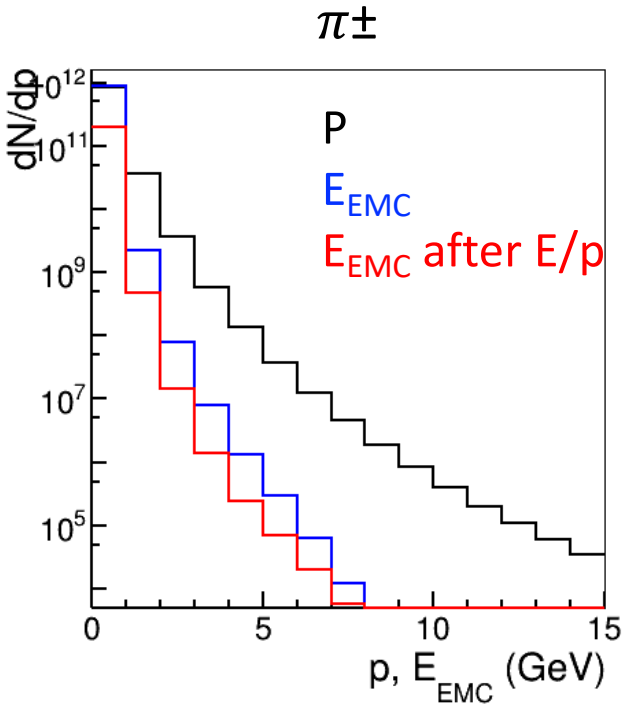
Assumption for EMCal resolution

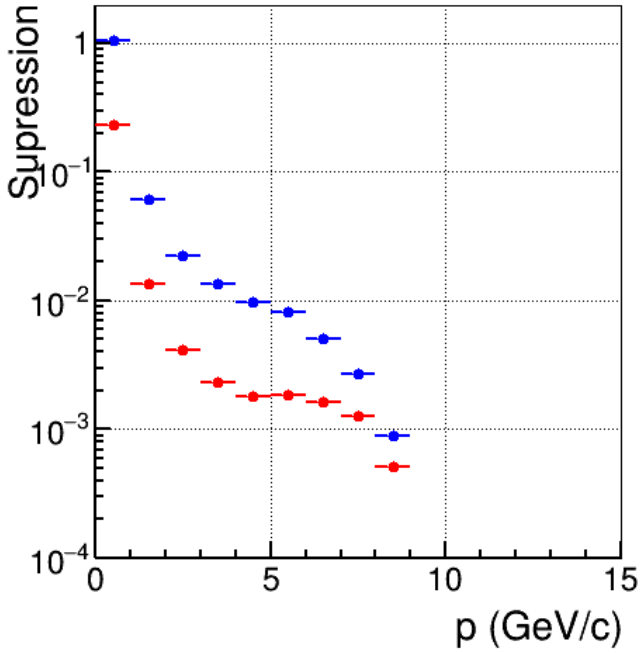
-4<η<-2	-2<η<-1	-1<η<1
$\frac{\sigma_E}{E} = \frac{2\%}{\sqrt{E}} \oplus 0.5\%$	$\frac{\sigma_E}{E} = \frac{7\%}{\sqrt{E}} \oplus 2\%$	$\frac{\sigma_E}{E} = \frac{12\%}{\sqrt{E}} \oplus 2\%$

Inclusive DIS: Hadronic Background Suppression



e+p 18x275 GeV
-2<η<-1

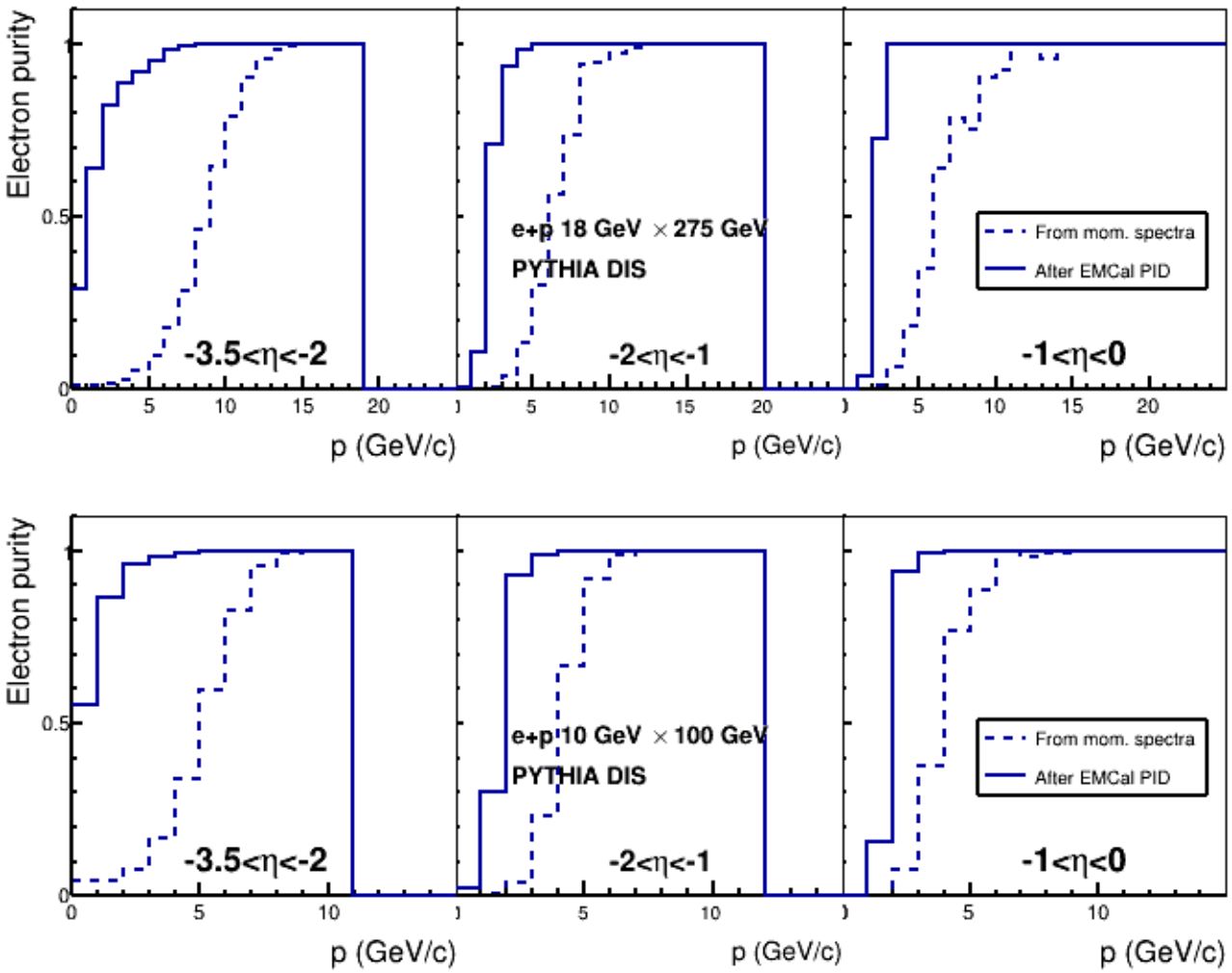




>10^2 charged hadron suppression at >4 GeV/c due to **EMCal response**
~10^3 charged hadron suppression at >4 GeV/c after **E/p cut**

DIS scattered electron purity

Purity = e / (e+h)



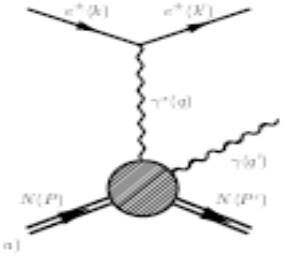
Background suppressed with:
- EMC response to h±
- E/p cut

Clean eID at >3-5 GeV/c

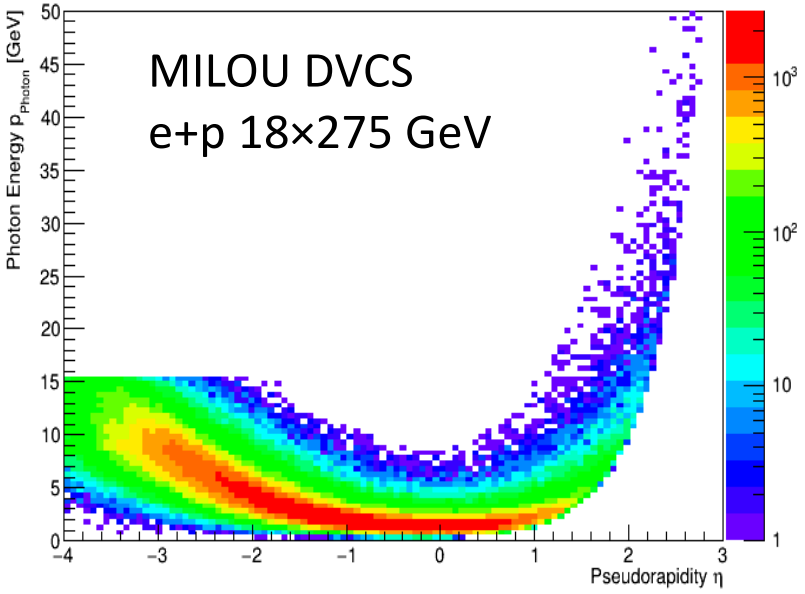
Clean eID at >2 GeV/c

Need additional detectors for eID at p<3-5 GeV/c

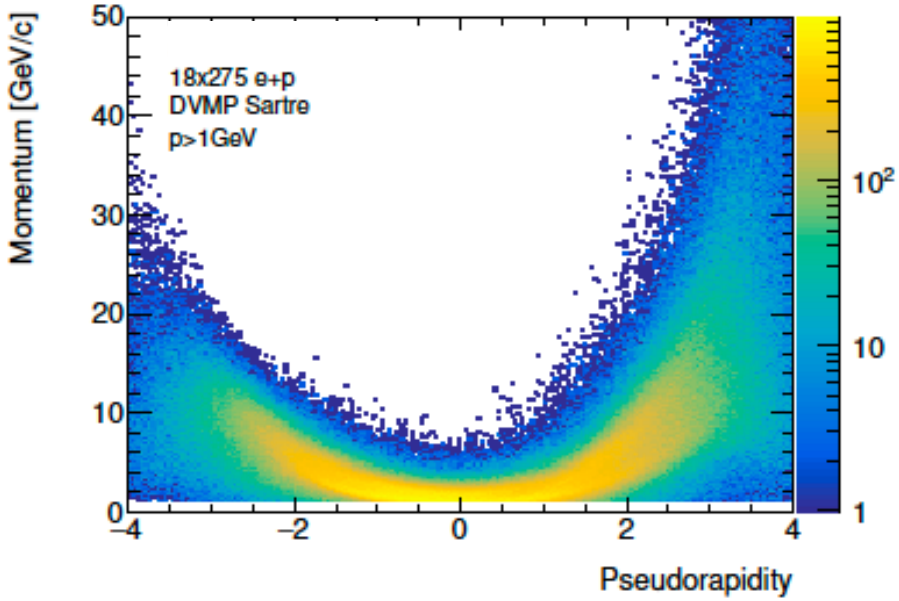
Exclusive DIS: DVCS and DVMP



DVCS photon kinematics



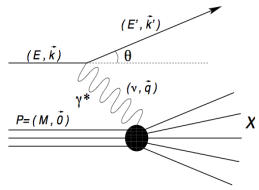
J/ψ→ee kinematics



Wide rapidity coverage is crucial

Resolutions

$$Q^2 = 4EE'\sin^2\left(\frac{\theta}{2}\right) \qquad y = 1 - \frac{E'}{E}\cos^2\left(\frac{\theta}{2}\right) \qquad x = \frac{Q^2}{sy}$$



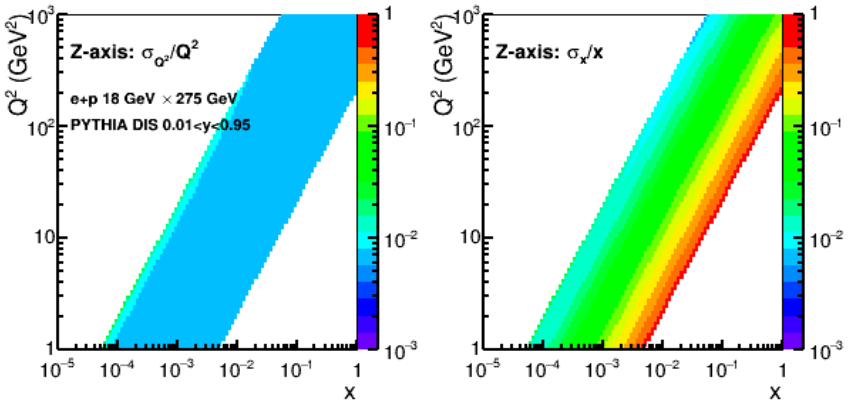
Resolutions for (x,Q^2)

For perfect angle measurements:

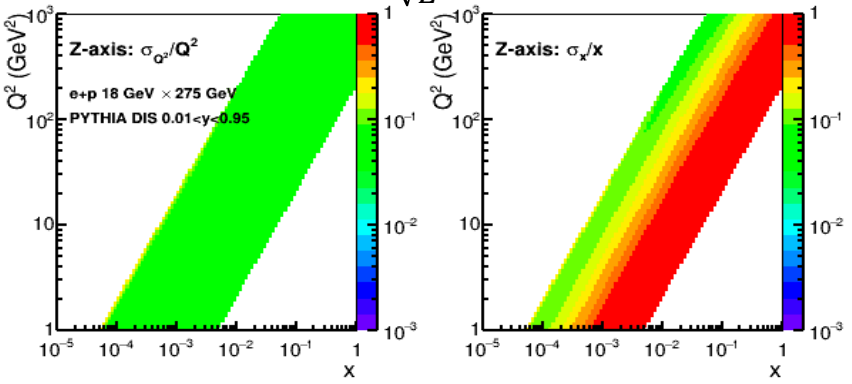
$$\frac{\sigma_{Q^2}}{Q^2} = \frac{\sigma_{E'}}{E'} \qquad \frac{\sigma_x}{x} = \frac{1}{y}\frac{\sigma_{E'}}{E'}$$

Defines the precision of unfolding technique to correct for smearing due to detector effects
Minimal effect from position resolution

$$\frac{\sigma_E}{E} = \frac{1.5\%}{\sqrt{E}} \oplus 0.5\%$$



$$\frac{\sigma_E}{E} = \frac{15\%}{\sqrt{E}} \oplus 2\%$$



Better resolution => wider kin. coverage

Tracking will provide better resolutions in some regions (mainly barrel)

Good EMCal resolution is particularly important in backward (e-going) direction:

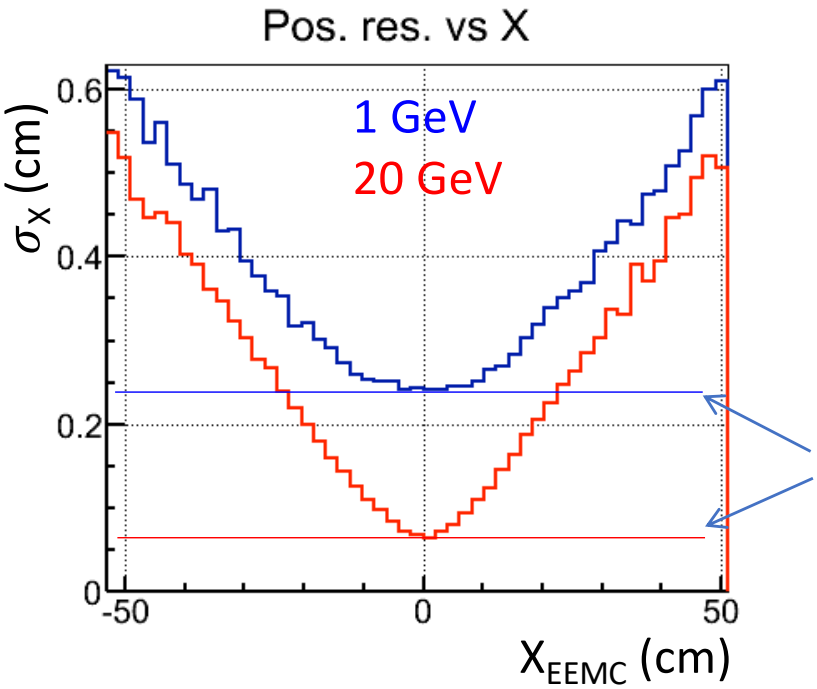
- Due to a general degradation of tracking performance close to the beam line
- Higher Q^2 kinematics (in barrel and h-going direction) can be extracted from final state hadron measurements (Jacquet-Blondel approach) … may not be true in eA

Projectivity

Non-projectivity:

- Deteriorates position resolution
- Deteriorates shower profile evaluation (for e/**γ** identification and π^0/**γ** discrimination)

GEANT4: Crystal endcap EMCal at z ~1.2m



For projective geometry

$$\sigma_X(E,\theta_X) = \sigma_X(E,0^0) \oplus d\sin(\theta_X)$$

For projective geometry

"Non-projectivity" term (from long. shower fluct.) d~X_0

Position resolution is dominated by "non-projectivity" term

Need to evaluate the impact on physics measurements

Granularity and $\pi 0/\boldsymbol{\gamma}$ discrimination in EMCal (alone)

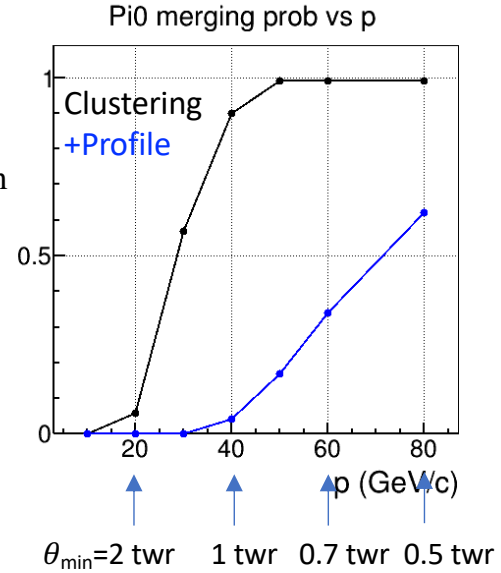
$$\theta_{min}^{\pi 0 \to \gamma\gamma} \approx \frac{2m_{\pi 0}}{E_{\pi 0}}$$

$\pi 0 \to \boldsymbol{\gamma\gamma}$:

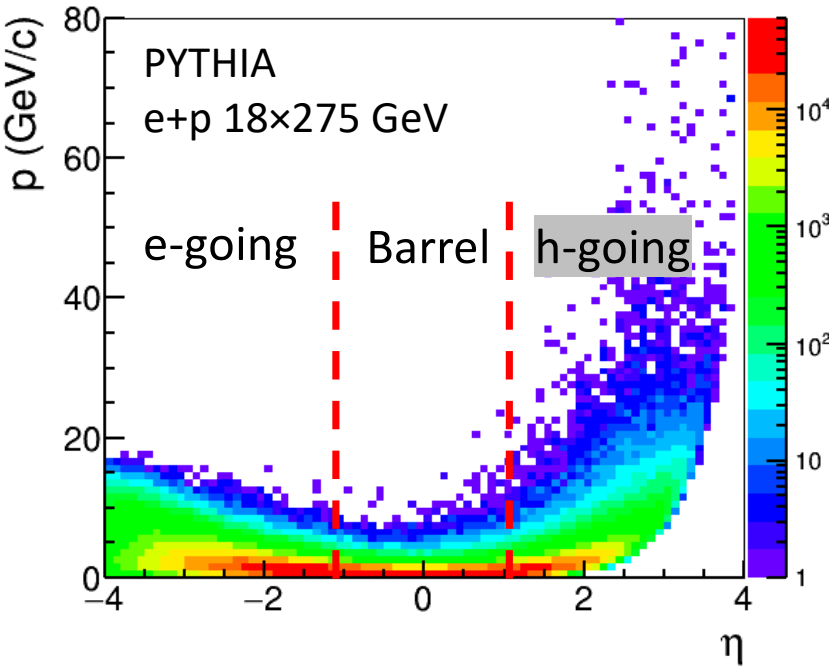
"Simple" clustering distinguishes two photons if they are separated by 1.5–2 tower distance in EMCal

Shower profile analysis distinguishes merged photons from single one if they are separated by 0.5–1 towers.

GEANT4:
Forward EMCal with granularity ~0.007 (2×2 cm^2 at z=3m)



Pion: p vs η



Pion momenta are limited by ~10 (~15) GeV/c in barrel (e-going) => Granularity of 0.03 (0.02) looks sufficient

<0.01 granularity may be needed for h-going

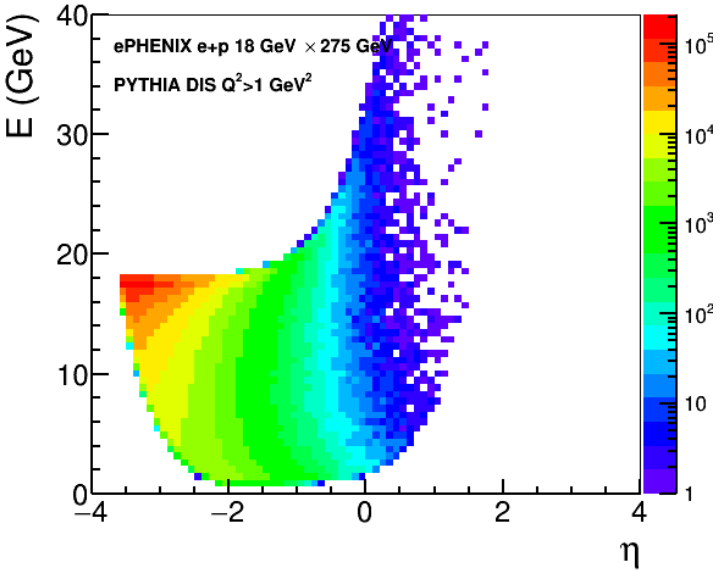
Conclusion

See comments/conclusions on my slides

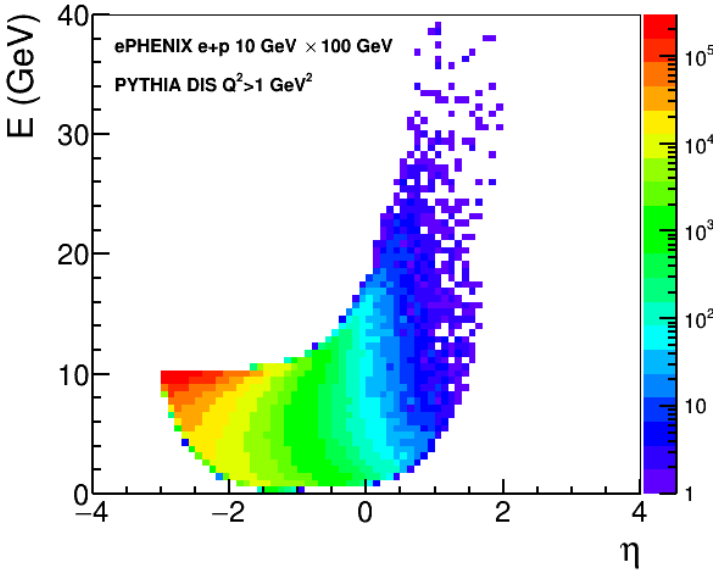
Backup

E vs η

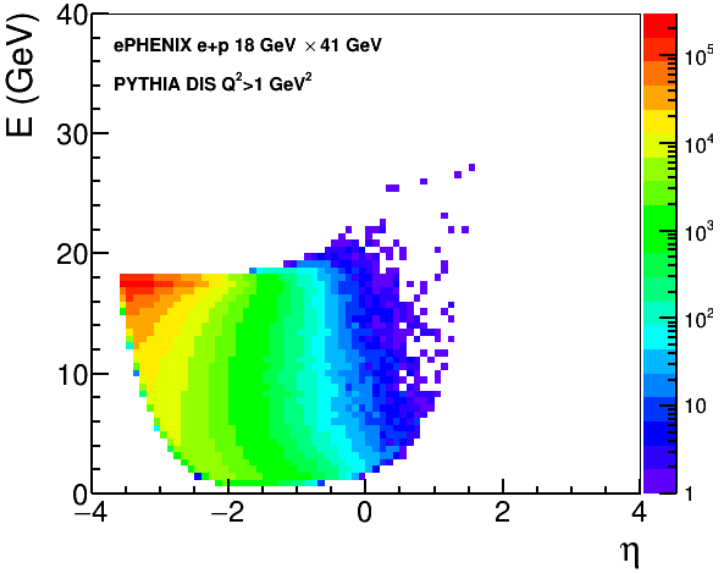
e+p 18x275 GeV



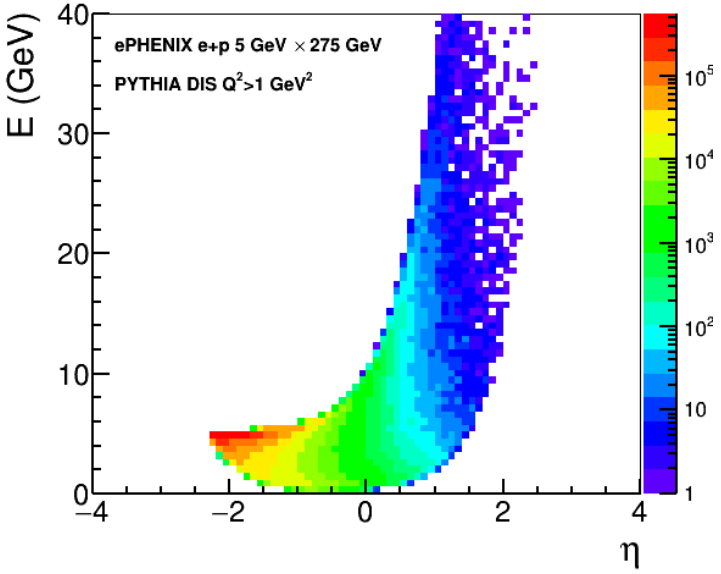
e+p 10x100 GeV



e+p 18x41 GeV

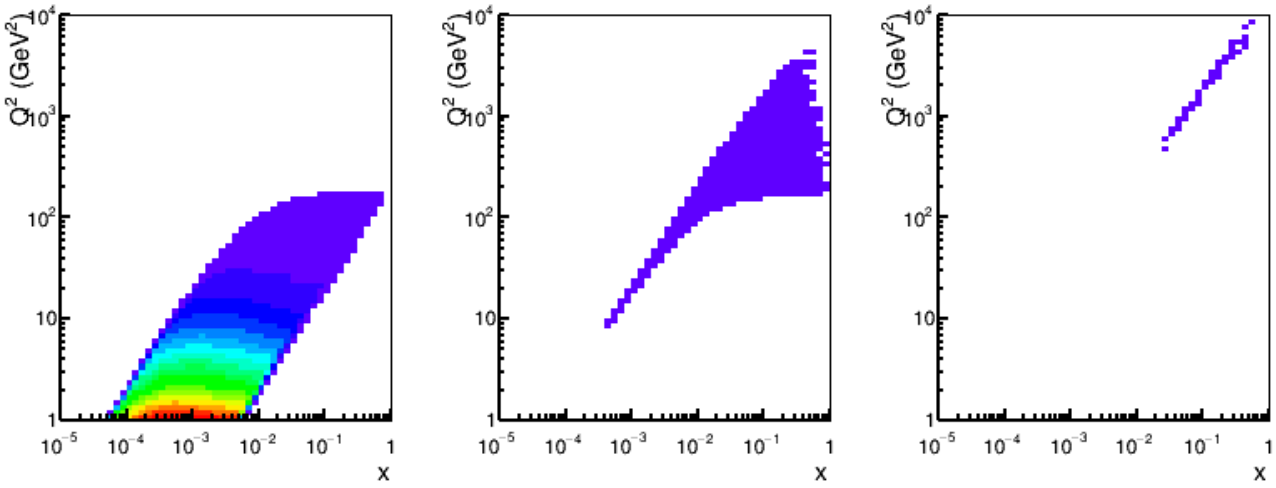


e+p 5x275 GeV

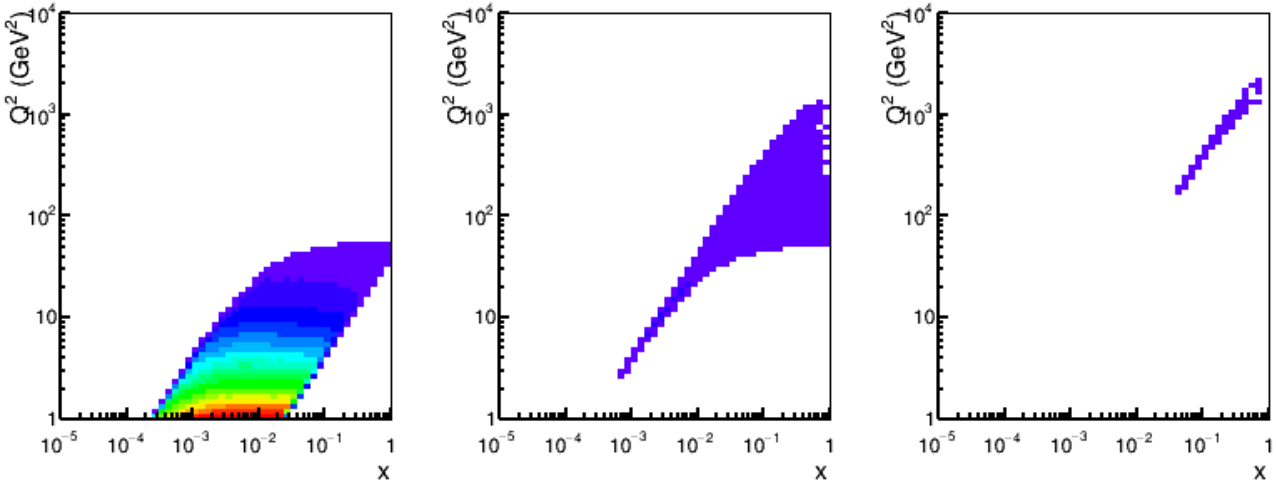


Q2 vs x

η<-1 (e-going) -1<η<1 (barrel) η<1 (barrel)



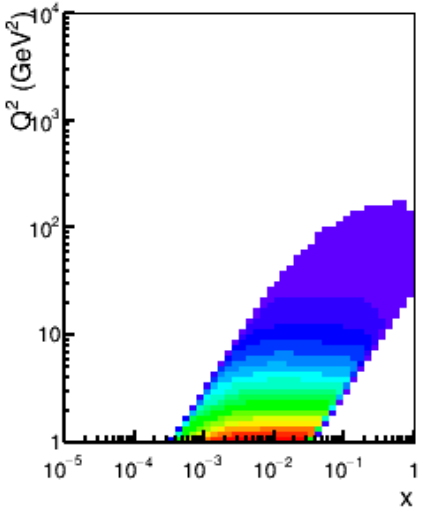
18x275 GeV

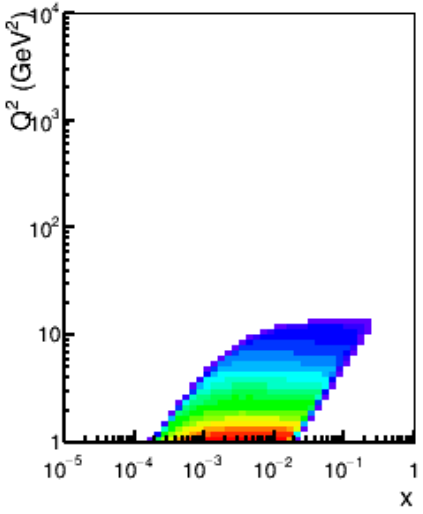


10x100 GeV

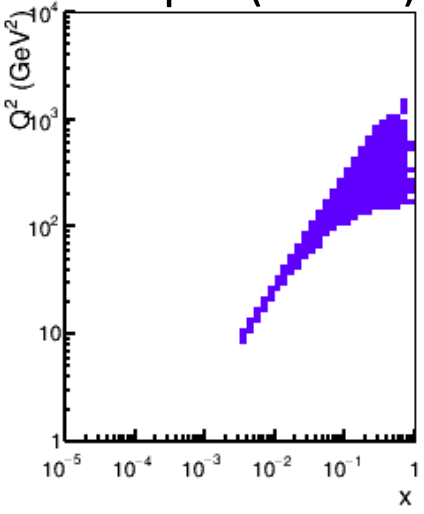
Q2 vs x

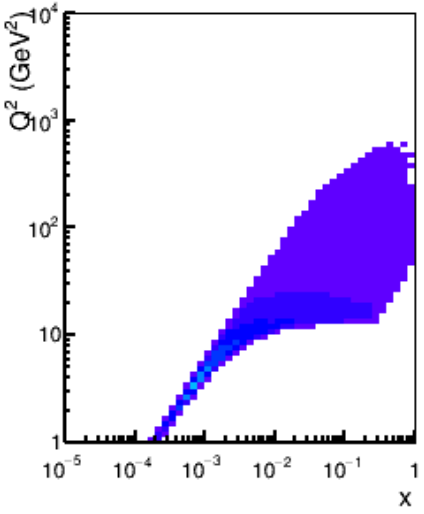
η<-1 (e-going)



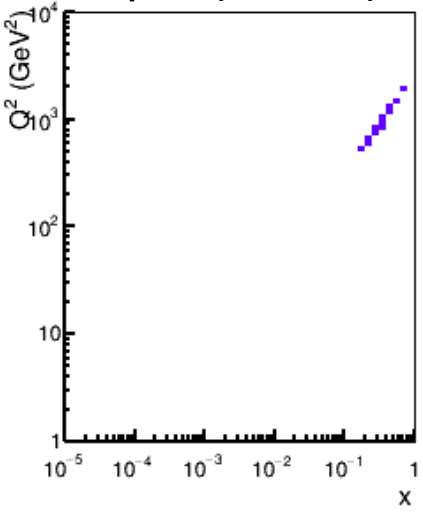


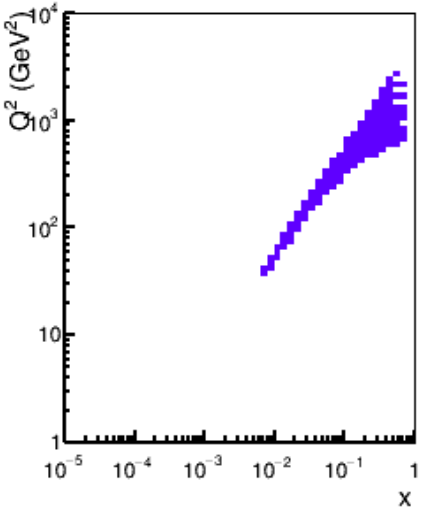
-1<η<1 (barrel)





η<1 (barrel)

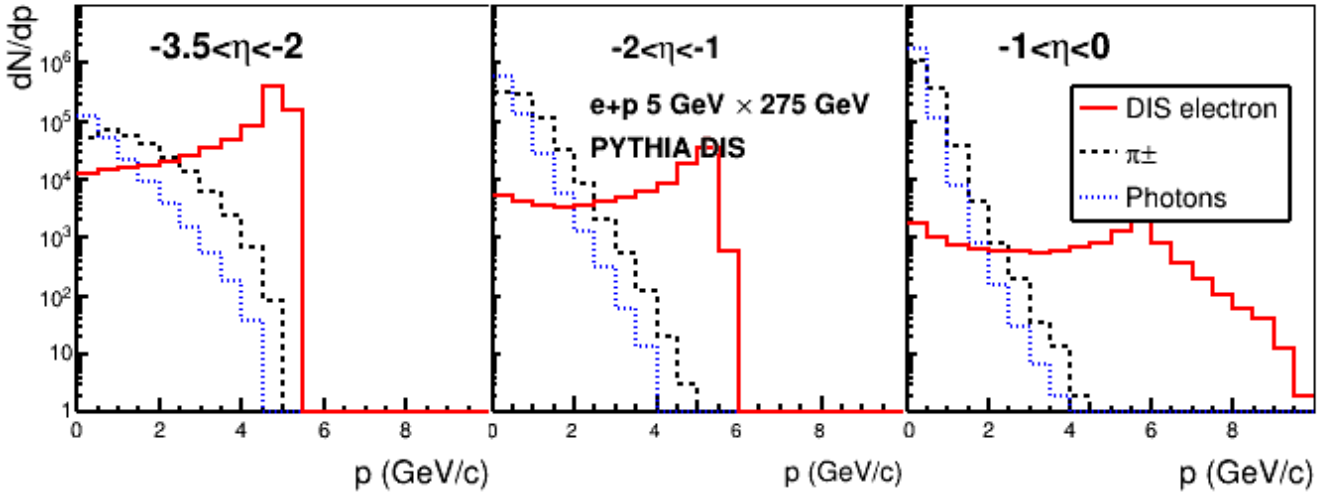


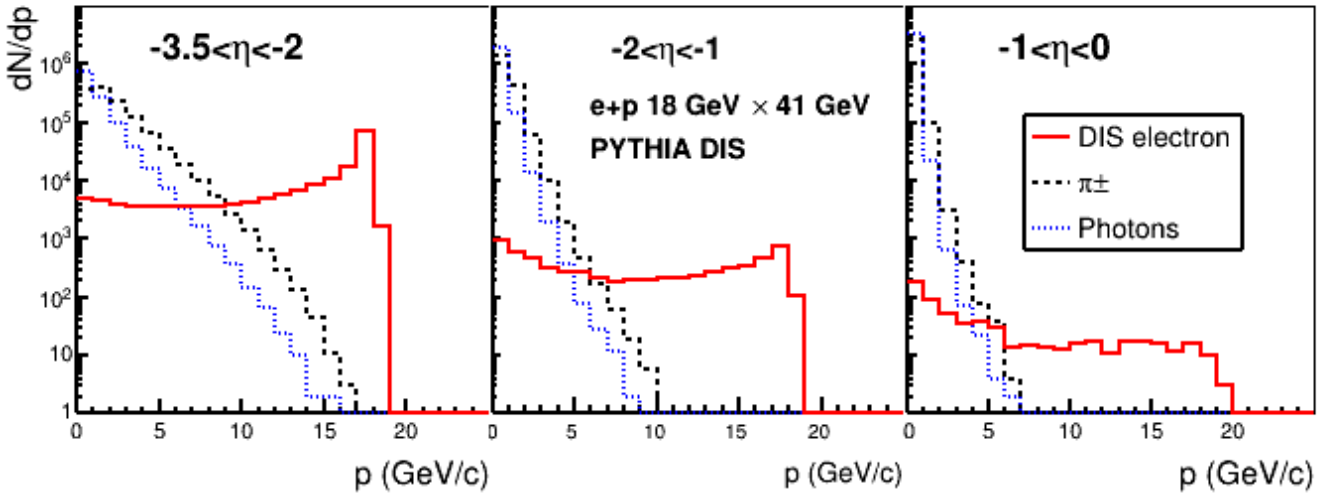


18x41 GeV

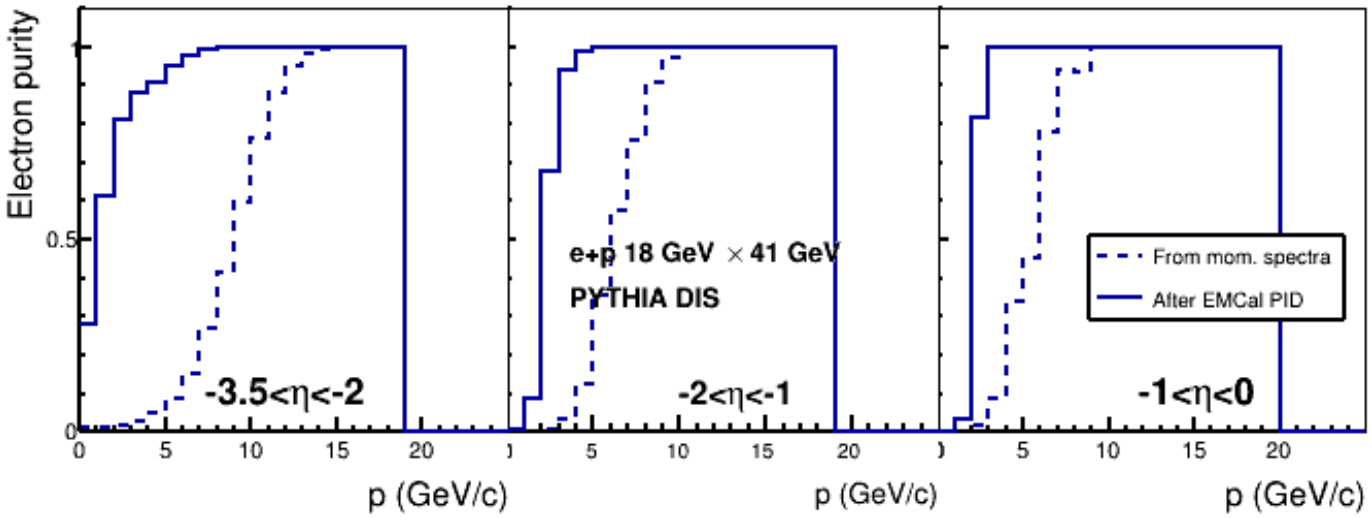
5x275 GeV

Inclusive DIS: background

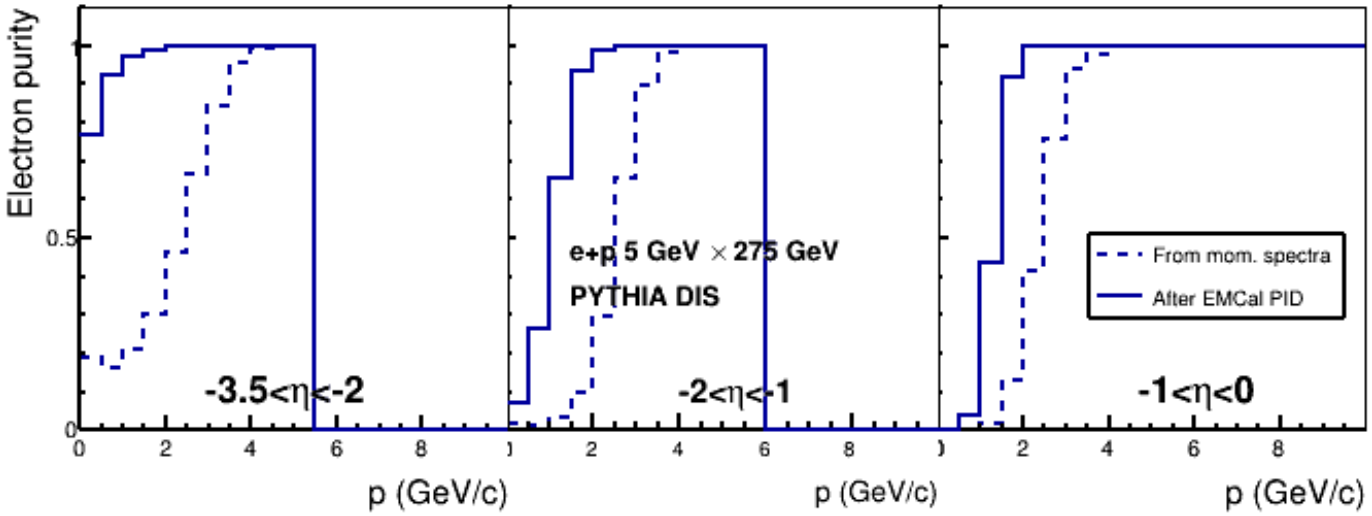




DIS scattered electron purity

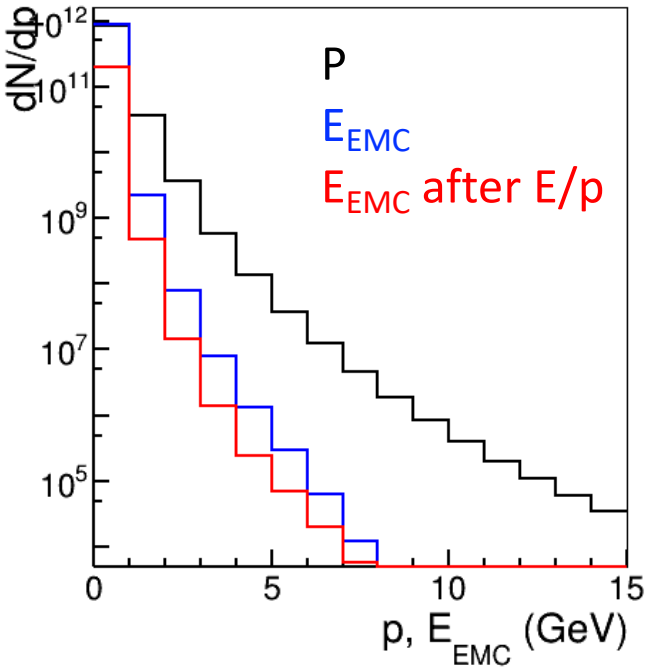


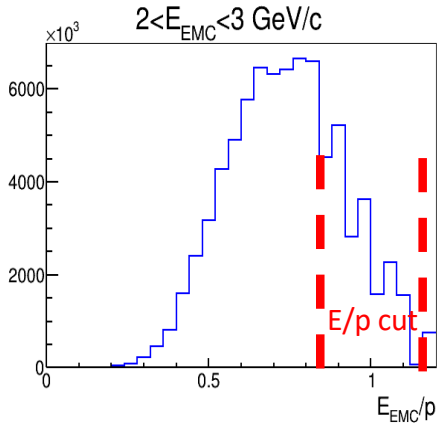
Clean eID at >3-5 GeV/c

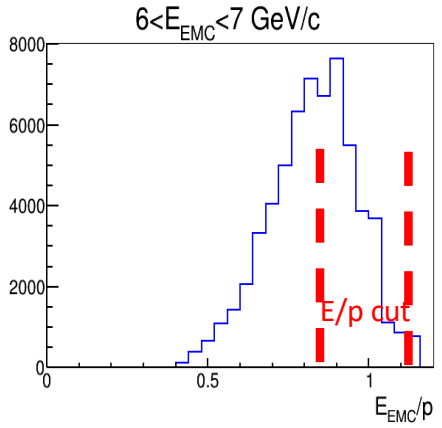


Clean eID at >1.5 GeV/c

Inclusive DIS: Background Suppression



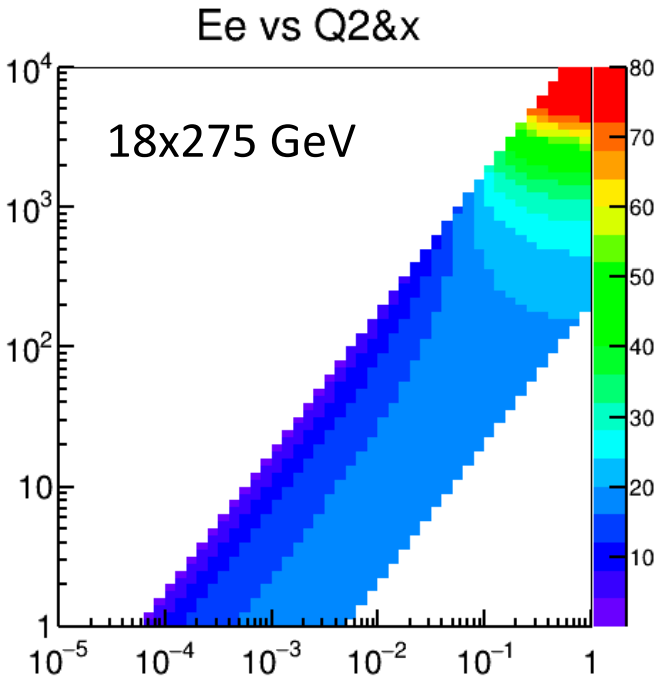


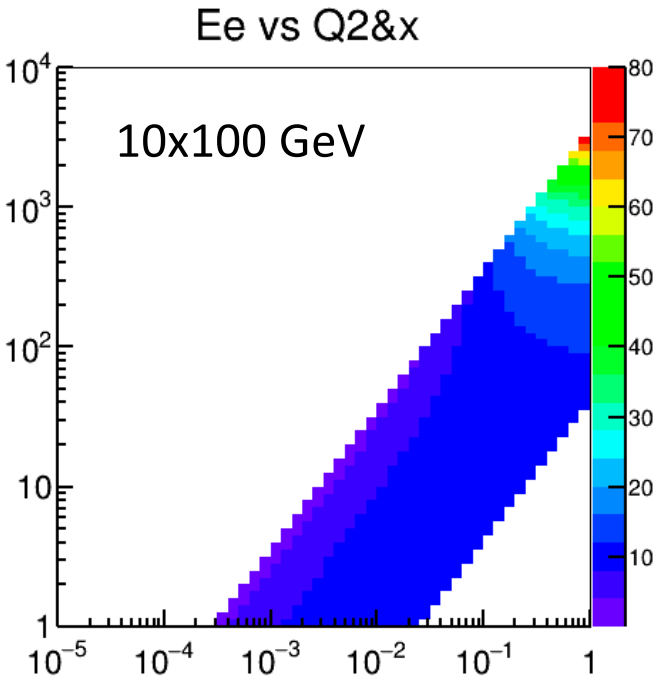


Effect of sharply falling spectrum:

Effectively selects hadrons with high E/p ratio

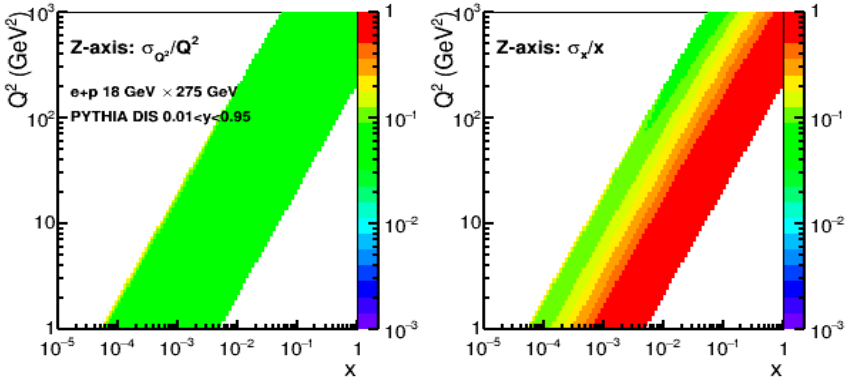
E_e vs x&Q^2


Ee vs Q2&x
18x275 GeV
10^4
10^3
10^2
10
1
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
80
70
60
50
40
30
20
10


Ee vs Q2&x
10x100 GeV
10^4
10^3
10^2
10
1
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
80
70
60
50
40
30
20
10

EMCal vs Tracking

EMCal only



$$\frac{\sigma_E}{E} = \frac{15\%}{\sqrt{E}} \oplus 2\%$$

Tracking only